

# ROOFTOP

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Breakout Session  
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# 1. For grid connected systems, what electrical components are necessary between the module and the grid? What is the state-of-the-art performance for each of these components?

1. Wiring, disconnects, combiner boxes, transformer, used to use rotating machines for AC-DC conversion,
2. Make components as off the shelf as possible
3. Discussion about disconnects on both sides of the conversion – best practice is only one
  - Conventional DC bus to grid-tied inverter
  - AC modules direct to grid
  - DC/DC converters on modules with grid-tied inverter

## 2. What are the critical attributes for a rooftop mounted converter? EXPLAIN. How do the above architectures compare for each of these attributes?

- Efficiency over a range (define range) of input powers and voltages?
  - 98-98.5% as flat power curve as possible
  - 200-500 kW
- Operating temperatures?
- Weight?
  - Matters, eliminate a lot of conduit and wiring if you can put it on the roof
- Size?
- Can't work with bipolar devices if going HVDC, going high frequency
- Enabling longer strings would be transformational
  - Bypass diodes kick in faster than in shorter strings
- Off the shelf components
- Field replaceable
- Have to consider fire protection – can build in protection in power electronics that take this into account
- Auto-shutoff, ground fault, can start to build a lot of the regulatory issues into the power electronics and thus reduce cost
- Have to look carefully at O &M costs when you switch to many smaller power electronics built into modules
- Have to consider life of the roof when you add system

### 3. For commercial buildings, how realistic/important is DC distribution within the building envelope? How large a market could this represent? What are reasonable bus voltages to consider?

- Going to be tough because manufacturers are using AC
- Unless your building is a microgrid, economics don't work
  - There may be markets where it makes sense but those markets are relatively small so as to not really have an impact
- Maybe for certain lighting loads, datacenters
- Would this be a cost savings? – could be
- High frequency and high voltage is an ARPA-E type of thing
- \*\*\*specialized applications but not really an opportunity space
  
- Could look like a utility installation
- Limitation to 600VDC
- Huge jump in UL listing from 600V to 1000V+ in terms of permitting, code standards
- Harmonizing the standards would be huge, but not an ARPA-E play
- Need DC arc protection
- Going to resistively grounded system has many benefits, don't need intelligent systems

## 4. What are the benefits and risks for module-scale MPPT for roof-top installation?

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- Densely packed modules? How much can this save?
- Easier (standardized) site design and layout? How much can this save?
  - Some say 15-20%
  - Some say just a few percent
- Cost ? Reliability?
  - Unlikely to be a cost wash compared to current systems
- Follow up question: why stop halfway, go all the way to AC, a full AC system going to the grid has a higher probability of reducing permitting and interconnection costs (some agree for residential, not all agree for large rooftop commercial system)
- This is a must on the module level – get more energy production, 15-20% more
  - Real issue is LCOE, have to be at parity with energy, not capital cost
  - Some disagreement about this – degree of mismatch involvement is under dispute, may just be a few percent
  - For installers there may be an advantage- don't have to site as carefully
  - Maybe don't have to do it on all the modules, maybe just every few
  - This can be better, but lots of people are doing it, ARPA doesn't have a role here
  - Communications integration is a great need
  - Impact on the thermal system is a concern

## 5. What are the standard measures of inverter reliability? Under what test conditions. How do they differ for rooftop and ground mounted systems?

- Have to go through the same torture tests as module does
- Temperature is higher because you're trapping the heat within the heat – large temperature gradient
- Inverters will be larger (for central)
  - Ground systems need more infrastructure in place
  - Very tough to work on the roof
- Wiring costs, and electrical losses, would be reduced if inverters are moved to the rooftop
- Not a big issue that ARPA-E would be able to work on
  - Except in big cities – no space to place a large inverter + transformer
- Make inverters lighter, more reliable, account better for thermal gradient

## 6. What are the critical diagnostic capabilities required of the inverter?

- Fault detection and management
  - Already taken care of for most inverters
- Module monitoring
  - How do you communicate and react on the data
  - Communications may be a play for ARPA-E
    - Reliability, efficiency
    - Predicted failure
    - Build in the intelligence into module
    - Could have same problem as utility smart grid – too much data needs to be handled and managed
      - » Would data mining be a solution?
    - Need data but more importantly you need a way to act upon the data otherwise it's pointless to gather the data
    - There is a right balance between monitoring entire array and all individual modules, but it is not clear yet what is the right amount to monitor
    - Have a way to automate monitoring and action – can't have a person actively watching
    - Cost of monitoring is nothing compared to the cost of the system
    - Initially there would be a cost reduction, but turns into a reliability increase over time
    - Monitoring and then how we share data with outside world
    - Data might be more useful for utility than for individual users
    - Need protocols
    - Can also use modeling and statistics to predict performance rather than acquire all data

# Discussion about codes/permitting

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- Interconnection fee, permitting costs are too high
- Lack of understanding of the NEC
  1. Impacts permitting, installation; how they interpret the NEC as it pertains to PV systems has not changed
  2. Local inspectors don't understand differences between thin film, Si – need education
  3. Permitting becomes town specific – need to have a standard way of permitting



# Needs identified

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- Breakers with arc-fault
- Reliability
- DC arc protection
- Communications on microinverters, MPPTs
- Increasing the throughput of the installer
- Need interface standards so you could use multiple panels within a standard

# Other

- Power electronics reliability is starting to approach the lifetime of solar panel lifetimes
  - Nobody with a big name will give you a 20 year warranty for a power electronic
- The interconnect fails in the module
- Large roof versus small roof
  - Sometimes easier to install, more stuff on a small roof, O&M may be easier too
- Most of service calls are for fixing connections – lots of failures in connectors
  - Not everyone has had the same experience
  - Have limited number of connections – really robust connectors are really expensive
- Power electronics are really hot right now, but need to be pulled into the 21<sup>st</sup> century
- Solar industry needs to standardize and unify their needs, similar to what the automotive industry has accomplished
- Need predictable market (policy, etc.)
- Solar industry is designed around components from other industries
- Needs to be more communication on how the supply chain is evolving

# Spec this new inverter, what would it look like that would be game changing?

- Inverter is not a game-changer for the system
- Big systems
  - Not going to change the business
- Smaller systems (residential)– there is an opportunity
  - Up to about 200 kW
  - Allow installer to install much faster, lower overhead
  - Scalability
    - Architecture with simple layout tools, gets to microinverters
  - 3 things – would be game-changer for installer
    - MPPT as reliable as the module
    - Absolute efficiency, 99%
    - Low cost
    - Integrated part of the module
    - Game-changing part is eliminating complex design process
  - Very similar to what we have in the current J box
    - AC, MPPT, communication, form factor, weight, efficiency
  - DC without inverter only for niche markets

# Key Points

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- Standardization
  - Reduction in installation costs
  - Use multiple (standard) panels within an installation
  - Who's in charge of making the standards?
  - Permitting is a town-by-town process, needs to be unified
    - Disconnects
  - Lack of understanding of NEC and how it relates to PV installations
- Reliability and Testing
  - Operation and warranty is very different
    - We can make components reliable, but providing them warranties is different
  - Diagnostics
    - Local system operation
    - Sharing data with outside world (utility)
- Communicate with entire supply chain and leverage new technologies from other fields (automotive)

# Key Points

- Communications enable reliability, but an actionable plan is required
  - Cyber security is critical
  - Protocols are required
  - What do you do with all the data? (Data mining)
- DC distribution would fulfill specialized needs (datacenters, lighting) but is impractical on the large scale
  - No standard parts at the moment
- Maximum Power Point Tracking (MPPT) and inverter topology
  - LCOE should be the metric, not capital cost
  - Maintain MPPT and inverter functions on the module
  - It is unclear what level of granularity is needed in MPPT/inverter implementation



- The ideal inverter would be transformational on smaller-scale installations (i.e. residential)
  - 99% efficient, same reliability as module, smaller form factor, lower weight, integrated communications & intelligence, MPPT, integrated into the module, low cost